MINE AND COLLISION PROTECTION FOR PASSENGER VEHICLE

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to wheeled transportation vehicles, more particularly to methods and devices for protecting passengers of such vehicles from harm associated with deleterious events such as mine explosions and severe collisions.

[0003] It is desirable to protect passengers of a motor vehicle from death or serious bodily injury that they may incur when their motor vehicle encounters highly destructive forces such as associated with explosions and collisions. Passenger protection has been a concern for both military and commercial vehicles, the former being particular vulnerable when riding over land mines or otherwise being subjected to explosive forces.

[0004] Some current approaches for affording mine and/or crash protection are based on providing additional structural protection in the form of armor made of higher strength and hardened metals such as high hard steel. Further, the automotive industry is conducting crashworthiness tests for investigating various designs of bodies that can absorb energy through large plastic deformations. The use of metallic foams is also being explored by auto manufacturers in some of the "high-end" vehicles. To date, the passenger protection methodologies have proven to be excessive in terms of additional weight and/or additional expense.

[0005] AM General Corporation manufactures the "High Mobility Multipurpose Wheeled Vehicle" (abbreviated "HMMWV" and popularly referred to as "HUMVEE"®), a highly mobile four-wheel-drive U.S. military vehicle that provides a common light tactical vehicle capability. The HMMWV entered U.S. Army service in 1985, replacing the quarter-ton jeep and other vehicles. The HMMWV can be configured in a variety of vehicular modes, e.g., troop carrier, armament carrier, ambulance, scout vehicle, etc. Although the HMMWV military vehicles serve their missions well, they are notoriously vulnerable to enemy attack, particularly those implementing land mines and other explosive capabilities.

SUMMARY OF THE INVENTION

[0006] In view of the foregoing, it is an object of the present invention to provide an improved methodology for structurally enhancing wheeled vehicles for protecting

passengers from death or serious bodily injury when the vehicles encounter explosive and/or mechanical impacts.

[0007] Other objects of the present invention are to provide such a methodology that is characterized by lower weight and lower cost as compared with conventional methodologies for accomplishing similar types of protection through structural enhancement.

[0008] The present invention represents a lighter, more affordable, more effective way of developing the needed force protection for wheeled vehicles. The present invention was primarily motivated by the need to afford better mine and crash protection to military personnel when riding in susceptible vehicles such as high mobility multipurpose wheeled vehicles (HMMWVs). Typically, inventive practice is not directed at preventing damage to the vehicle; indeed, under usual destructive circumstances a vehicle will incur significant damage, frequently beyond repair, despite inventive practice. Rather, what is normally the primary purpose of the present invention is to protect the occupant or occupants of the vehicle.

[0009] Typical inventive method embodiments are for rendering a vehicular cabin assembly more occupant-protective. The cabin assembly includes a cabin body, four wheel-facing bulkheads and two floorboards separated by a space therebetween. Each bulkhead adjoins a floorboard. The inventive method comprises providing shielding means for the cabin body, the providing shielding means including: (a) at each bulkhead, establishing a sandwich construction that includes the bulkhead, elastomeric material, and

non-elastomeric material, wherein the elastomeric material is sandwiched between the bulkhead and the non-elastomeric material; (b) at each floorboard, establishing a sandwich construction that includes the floorboard, elastomeric material, and non-elastomeric material, wherein the elastomeric material is sandwiched between the floorboard and the non-elastomeric material; and, (c) at least substantially covering the space between the floorboards, the at least substantially covering including attaching to the cabin assembly a double-layer construction that includes elastomeric material and non-elastomeric material, wherein the elastomeric material is underneath the non-elastomeric material.

[0010] According to typical inventive vehicular embodiments, the inventively enhanced wheeled vehicle is a vehicle that is attributed with occupant protectiveness against injurious force encountered by the vehicle. The inventively enhanced vehicle comprises a cabin body, a cabin underside, two pairs of axial wheels, and two pairs of wheel well areas. The cabin underside includes two side floorboard areas and a non-floorboard area intermediate the floorboard areas. Each wheel well area is associated with a wheel. The floorboard areas and the wheel well areas are each characterized by a laminar configuration that includes two rigid layers and an elastomeric layer therebetween. The non-floorboard area is characterized by a laminar configuration that includes a rigid layer and an elastomeric layer wherein the elastomeric layer faces downward.

[0011] According to usual practice of an inventively enhanced vehicle, the floorboard areas, the non-floorboard area and the wheel well areas collectively form a buffer for the cabin. The buffer generally describes a dish shape. The inventively-enhanced vehicle has a front end and a rear end. Each floorboard area adjoins a front

wheel well area and a rear wheel well area; the floorboard area, the front wheel well area and the rear wheel well area, in combination, generally describe a bracket shape. The non-floorboard area adjoins the floorboard areas; the non-floorboard area and the adjoining floorboard areas, in combination, generally describe a planar shape. In response to injurious force encountered by the vehicle, the buffer acts to deflect the impact and to dissipate the energy that are associated with the injurious force.

[0012] The inventive principles are applicable to multifarious types, sizes and styles of wheeled vehicles. In furtherance of affording this kind of protection, the present invention features the incorporation of elastomeric material and rigid (metallic or non-metallic, e.g., composite) material at strategic locations on the lower part of the vehicle. The present invention focuses upon two general areas, viz., the wheel well areas of the vehicle's underbody, and the cabin structure area of the vehicle's undercarriage (i.e., the underside of the cabin frame).

[0013] More specifically, the main regions of interest according to typical inventive practice are as follows: (i) the generally vertical, frontward facing region of the front left ("driver's side") wheel well; (ii) the generally vertical, frontward facing region of the front right wheel well; (iii) the generally vertical, rearward facing region of the rear left wheel well; (iv) the generally vertical, rearward facing region of the rear right wheel well; (v) the left floorboard region of the portion of the undercarriage that corresponds to the cabin; (vi) the right floorboard region of the portion of the undercarriage that corresponds to the cabin; (vii) the central region of the portion of the undercarriage that corresponds to the cabin.

[0014] In every such region, the inventive add-on structure includes an elastomeric layer (such as that which is applied through molding, casting, spraying or bonding) and a non-elastomeric layer (such as a sheet or plate made of a metal or composite or other non-metal material). In the context of inventive practice, a non-elastomeric layer is also referred to herein as a "rigid" layer (or "stiff" layer), since a non-elastomeric layer is characterized by a degree of rigidity (or stiffness) so as to be more rigid (or stiff) than an elastomeric layer. In each of regions (i) through (iv), the elastomeric layer is sandwiched between the existing wheel well surface and the rigid layer (e.g., a metallic or composite plate). In each of regions (v) and (vi), the elastomeric layer is sandwiched between the bottom floorboard surface and the rigid layer (e.g., a thin sheet that is metallic or composite). In region (vii), the rigid layer (e.g., a metallic or composite plate) is attached (e.g., bolted or adhered) to the undercarriage's central region (which, in a typical motor vehicle, is largely open or discontinuous), and the elastomeric layer is disposed next to the rigid layer so that the elastomeric layer faces downward and is nearer to the ground that the rigid layer.

[0015] Typical practice provides for use of an elastomeric material that is highly elastic or highly viscoelastic, e.g., characterized by a strain-to-failure of at least 100%, more typically at least 300% to 400% or greater. The present inventors style their elastomeric layer (which contributes to the mine and crash protection of the passenger or passengers) an "explosion resistant coating," or "ERC." The ERC material can be practically any elastomer, polymeric or non-polymeric, such as polyurea (a mixture of polyurethane and urea), polyurethane, or rubber. According to typical inventive practice,

the inventive ERC has high strain-rate dependence and hardening characteristics to provide shock wave interaction, energy absorption, and prevention of fracture penetration under extreme loads such as mine explosion. Inventive principles are also applicable for crashworthiness purposes to prevent structural damage and reduce acceleration effects on the vehicle's occupants. Regardless of the source of the extreme loading, inventive practice succeeds in avoiding or minimizing injury and fatality.

[0016] The present invention's layered configuration provides protection against blasts and collisions at significantly lower weight and cost than does the existing technology. Because of the reduced weight associated with the inventive elastomer (ERC), the present invention's double-layered combination (one elastomeric layer, one non-elastomeric layer) can be added to a military vehicle without changing the mission capability of the vehicle. Further, the ERC can be applied via casting in place, spraying, or bonding a separate cured piece of elastomer. Because of the varied techniques and procedures at the practitioner's disposal for installation of the ERC, the ERC can be added to areas of vehicles that do not lend themselves to addition of other types of protective materials.

[0017] Although the present invention is of considerable value when involving "retrofitting" of the inventive enhancements with respect to an existing vehicle, the present invention can also be practiced to great effect in the context of vehicle manufacture so that the original vehicles leave the factory with inventive enhancements.

[0018] Other objects, advantages and features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** through **FIG. 4** are driver side elevation, front elevation, rear elevation and underside plan views, respectively, of a high mobility multipurpose wheeled vehicle (HMMWV) that has not been enhanced in accordance with the present invention. **FIG. 4** also reveals some interior detail.

[0020] **FIG. 5** is a driver side elevation view similar to the view shown in **FIG. 1**, wherein the vehicle shown in **FIG. 1** through **FIG. 4** has been protectively enhanced by elastomeric and non-elastomeric materials in accordance with the present invention.

[0021] **FIG. 6** is a partial driver side elevation view representing the front half of the inventively enhanced vehicle shown in **FIG. 5**, particularly illustrating the layered construction (adjacent elastomeric and non-elastomeric layers) that is inventively applied to each of the two lateral cabin underside areas of the vehicle.

[0022] **FIG. 7** is a partial driver side elevation view representing the front half of the inventively enhanced vehicle shown in **FIG. 5**, particularly illustrating the layered construction (adjacent non-elastomeric and elastomeric layers) that is inventively applied to the central cabin underside area of the vehicle.

[0023] **FIG. 8** is a front elevation view of the inventively enhanced vehicle shown in **FIG. 5**.

[0024] **FIG. 9** is a rear elevation view of the inventively enhanced vehicle shown in **FIG. 5**.

[0025] **FIG. 10** is a bottom plan view of the inventively enhanced vehicle shown in **FIG. 5**.

[0026] **FIG. 11** is an upper perspective diagrammatic view of an embodiment of an overall protective system in accordance with the present invention similar to that shown in **FIG. 5** through **FIG. 10**, particularly illustrating how the seven subsystems form the overall protective system in an enclosure-like configuration with respect to the cabin.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Referring now to **FIG. 1** through **FIG. 4**, high mobility multipurpose wheeled vehicle (HMMWV) **10** is a typical military passenger vehicle that is suitable for protective amplification in accordance with the present invention. The HMMWV **10** shown in **FIG. 1** through **FIG. 4** is a standard such vehicle that is not inventively enhanced. Vehicle **10** includes a body **12**, an undercarriage **14**, four wheels (tires) **16**, and four wheel wells **18**. Body **12** and undercarriage **14** are distanced above ground **99** by the wheels **16** and their associated axles.

[0028] Front left wheel **16FL** and front right wheel **16FR** share the front axle; rear left wheel **16FL** and rear right wheel **16RR** share the rear axle. Each wheel well **18** corresponds to a wheel **16**. That is, front left wheel well **18FL** is adjacent wheel **16FL**; front right wheel well **18FR** is adjacent wheel **16FR**; rear left wheel well **18RL** is adjacent wheel **16RL**; rear right wheel well **18RR** is adjacent wheel **16RR**. Each wheel well **18** is a wall-like or bulkhead-like structure that is designed to shield interior parts of vehicle **10** from objects such as flying debris occasioned by rotation of the corresponding wheel **16**.

[0029] Body **12** includes a cabin **20** for housing one or more passengers. The term "passenger" as used herein is synonymous with "occupant" or "traveler," referring to any person that is conveyed by the vehicle regardless of whether or not the person participates in the operation of the vehicle. Undercarriage **14** is divisible into three "longitudinal" sections, each extending from front to rear of vehicle **10**, viz., a lefthand (driver's side) lateral longitudinal section **22L**, a righthand lateral longitudinal section **22R**, and a medial longitudinal section **24**. Undercarriage **14** includes a cabin underside **26**, which is that portion of undercarriage **14** situated at the bottom of or directly beneath cabin **20**.

[0030] Cabin underside **26** includes three longitudinal regions, each longitudinal region being included as part of a longitudinal section, viz., a left floorboard region **28L** (which left longitudinal section **22L** includes), a right floorboard region **28R** (which right longitudinal section **22R** includes), and a central region **30** (which medial longitudinal section **24** includes). Floorboard regions **28L** and **28R** are continuous flat structures that represent the foundations for the passenger spaces. Situated intermediate floorboard regions **28L** and **28R**, central region **30** is the substantially open or discontinuous structure

that represents the foundation for the components (e.g., drive line, exhaust system, fuel tank) contained in a longitudinal-axial "hump"-shaped compartment located between the lefthand and righthand passenger spaces.

[0031] Reference now being made to **FIG. 5** through **FIG. 11**, standard HMMWV **10** is inventively enhanced so as to become explosion/collision-protective HMMWV **100**. In accordance with the present invention, blast and collision protection is provided though the selective add-on use of a two-layer laminar combination that includes an elastomeric layer **210** (also referred to herein as an "ERC coating") and a non-elastomeric layer **220** (also referred to herein as a "rigid" or "stiff" layer). The thicknesses of layers **210** and **220** are exaggerated for illustrative purposes in **FIG. 5** through **FIG. 11**.

[0032] In the wheel well regions **18** and the floorboard regions **28**, an inventive laminar system **200** is formed so that an elastomeric layer **210** is sandwiched between an existing structural portion of vehicle **10** (a wheel well **18** or a floorboard **28**, as the case may be) and a non-elastomeric (rigid) layer **220** such as a sheet metal mold material or a metal plate mold material. In the central region **30**, an inventive two-layer combination is joined to vehicle **10** so that a rigid layer **220** is attached to undercarriage **14** and an elastomeric layer **210** is disposed on the opposite side of the rigid layer **220** so that the elastomeric layer faces downward toward ground **99**.

[0033] Hence, a three-layer sandwich construction, laminar material system **200W**, is created in the wheel well **18** region; further, a three-layer sandwich construction, laminar material system **200F**, is created in each of the two floorboard **28** regions. In each three-

layer material system **200W** or **200F**, an elastomeric material is sandwiched between two rigid materials; that is, an elastomeric layer **210** is sandwiched between an existing rigid structural portion of vehicle **10** and a rigid layer **220**.

[0034] In contrast, laminar material system **200C** is a two-layer sandwich construction, not a three-layer sandwich construction. A two-layer material system **200C** is associated with the central region **30** wherein a rigid material **220C** coated with an elastomeric material **210C** is mounted below the substantially open centric area **30** of the vehicular underside; that is, a rigid layer **220** that is covered with an elastomeric layer **210** on the rigid layer's downward facing side is adjacent on the rigid layer's upward facing side to what largely constitutes a void in undercarriage **14**.

[0035] Depending upon the perceived threats to vehicle **10** and the locations of inventive structural association with respect to vehicle **10**, the rigid layer **220** will typically vary in the range between about 0.03 inches in thickness (e.g., sheet metal) and about 0.25 inches in thickness (e.g., mild steel). Regardless of the placement of an inventive rigid-elastomeric combination with respect to unenhanced vehicle **10**, elastomeric layer **210** and rigid layer **220** are coupled so that rigid layer **220** is next to elastomeric layer **210**. A variety of techniques are available to the inventive practitioner for covering rigid layer **220** with elastomeric layer **210**; for instance, elastomeric layer **210** can be castable or moldable wherein rigid layer **220** is the mold material. Alternatively, elastomeric layer **210** can be sprayed upon rigid layer **220**. As another option, a whole elastomeric layer **210** (an integral piece) can be bonded to rigid layer **220**.

[0036] As shown in **FIG. 5** through **FIG. 9**, a rigid member (e.g., steel plate) **220W** is mounted on each wheel well **18** so that an elastomeric material **210W** is situated therebetween, thus forming a three-layer elastomeric-sandwich construction **200W**. In the event of a mine explosion, steel "deflector" plate **220W** deflects the initial high impulsive loading of the explosion away from the driver and other occupant(s) of inventively enhanced vehicle **100**. The steel deflector plate **220W** and at least a portion of the aluminum wheel well **18** structure sandwich elastomer (e.g., polyurea) **210W** so as to impart confinement to the polyurea **210W**. The contour of front well **16FL** is visible to the observer, whereas that of rear wheel well **16RL** is hidden from view by the fender structure of vehicle **100**. As distinguished from the rectilinear front wheel wells **16FL** and **16FR**, the rear wheel wells **16RL** and **16RR** are depicted as being characterized by a degree of curvilinearity. Each plate **220W** is conformingly coupled with a substantially flat and nearly vertical portion of the corresponding front or back wheel well **16**.

[0037] Two defeat mechanisms are manifested at wheel wells **18** upon the occurrence of an explosion. As a general statement in materials science and engineering, an elastomer in a confined state will have orders of magnitude higher modulus and dynamic properties than will the same elastomer in an unconfined state. At wheel wells **18**, the sandwich construction (wherein an elastomer **210** is interposed between a stiff wheel well **18** and a stiff layer **220**) results in the generation of internal shock waves that dissipate the high impulse loading. Further, at wheel wells **18**, this sandwich construction provides a mechanism known as "constrained layer damping" so as to dissipate a very wide range of frequencies, after the initial shock loading.

[0038] The two abovementioned impact-thwarting mechanisms are also taken advantage of in the floorboard regions **28**. A rigid member (e.g., thin sheet metal or composite sheet) **220F** is mounted on each floorboard **28** so that an elastomeric material **210F** is situated therebetween, thus forming a three-layer elastomeric-sandwich construction **200F**. That is, on each of the lefthand and righthand sides and under both the front and back seats, the elastomer **210F** is sandwiched between the sheet metal **220F** and at least a portion of the floorboard **18F**. There are two notable distinctions between sandwich construction **200F** and sandwich construction **200W**, these distinctions being associated with the difference in thicknesses between rigid layer **200W** and rigid layer **200F**.

[0039] In this regard, as distinguished from three-layer material system **200W**, additional impact-thwarting mechanisms are present in the case of three-layer material system **200F**. The casting of the elastomer **210F** onto and underneath the floors (floorboards) **28** helps to protect cabin **20**, especially the cargo areas. When a frontal explosion occurs, three-layer material system **200F** reduces the vibrations of cabin **20**, thereby further reducing the impact acceleration ("g-forces") on the passengers. In the case of a vehicular rear explosion, by means of a momentum-trapping mechanism, three-layer material system **200F** prevents penetration of the cargo areas of the floors (floorboards) **28**.

[0040] According to typical inventive practice, at each floorboard **28** the rigid member **220F** is made of a thin material such as sheet metal or composite sheet. Since a thin rigid sheet **220F** lacks the stiffness of a thicker deflector plate **220W**, the sandwich

construction **200F** resists the explosion through shock reflections and prevents fracture and localization. The relative thinness of rigid layer **220F** thus gives rise to another defeat mechanism. Furthermore, the thin quality of rigid layer **220F** more naturally lends itself to a fabrication process whereby rigid layer **220F** is used for casting the elastomeric material (e.g., polyurea) **210F**, and doing so with a required thickness of the elastomeric material **210F**. The elastomeric material **210F** can be cast from inside through-holes provided in each floorboard **28** of vehicle **10**.

[0041] The bottom plate **220C** covers at least a portion of central region **30**. Plate **220C** (e.g., made of aluminum) is coated with elastomeric material **210C**, thus forming a two-layer construction **200C** that is positioned in the center of inventively enhanced vehicle **100**. Some inventive embodiments provide for a rigid plate **220** that is atachable and detachable, the removability of plate **220** thus facilitating access (e.g., for maintenance or repair) to interior parts of vehicle **100**. At least two mechanisms are manifest in association with plate **220C**. According to a first mechanism, plate **220C** protects by deflecting the blast or impact toward the ground **99**. According to a second mechanism, plate **220C** favorably alters the major undercarriage **14** frame vibration modes by providing nonlinear damping. The bottom plate **220C** converts the longitudinal frames to a box section with high vertical, lateral stiffness, as well as torsional stiffness, in addition to the large damping provided by the ERC **210C**. This significantly reduces the lateral and vertical accelerations of the vehicle during the explosion, and thus reduces the risk of injury. The elastomer **210C** interacts with the blast by generating internal shock waves,

thereby reducing the negative effect of plate **220C**, especially in terms of preventing or decreasing fracture and localization of plate **220C**.

[0042] As shown in **FIG. 5** through **FIG. 9**, the bottom surface of the elastomeric coating **210C** of plate **220C** is lower (nearer to ground **99**) than is the bottom surface of each sheet metal **220F** member. This illustrates not only that plate **220C** is thicker than each sheet metal **220F**, but also that the upper surface of elastomer **210F** is higher (further from ground **99**) than is the upper surface of plate **220C**. For illustrative purposes, the upper surface of elastomer **210F** is shown to be disposed above the bottom fender line in vehicle **10**. Further, the lower surface of elastomer **210F**, the upper surface of sheet **210F**, and the upper surface of plate **210C** are shown to be approximately coincident.

[0043] Testing conducted by the United States Navy in association with an HMMWV **10** demonstrated the efficacy of the present invention. The subject HMMWV **10**, similar to that shown in **FIG. 1** through **FIG. 4**, was about 190 inches (3.30 meters) in length, 86 inches (2.18 meters) in width, and 72 inches (1.83 meters) in height. The test vehicle **10** was largely constructed of aluminum, including in the wheel well **18** and floor board **28** regions. The ERC material **210** selected for this investigation was an "80 Shore A" castable polyurea.

[0044] In the process of converting this test vehicle **10** to an inventively enhanced vehicle **100**, a flat eighteen-gage (0.050 inch) steel sheet metal **220F** was used as a mold under each aluminum floorboard **28** for casting ERC **210F** under the floorboard **28**, beneath the corresponding passenger compartment. In each of the aluminum wheel wells

18, a one-quarter inch flat mild steel **220W** was used as the mold material for casting ERC **210W**. In both the wheel well **18** and floorboard **28** locations, the rigid mold **220** was attached to allow for a three-quarter inch gap between rigid mold **220** and the vehicular surface, and this gap was then filled with the ERC material **210**; that is, a three-quarter inch gap was provided between each combination of a rigid mold **220W** and a wheel well **18**, and a three-quarter inch gap was provided between each combination of a rigid mold **220F** and a floorboard **28**. Between the floorboard frames **28L** and **28R** and under the center of the vehicle **10**, a separate laminar construction **200**, viz., laminar construction **200C** (including an aluminum plate **220C** and an ERC **210C** facing thereon) was associated with vehicle **10** so that the bottom surface of ERC **210C** was distanced about 16 inches (0.41 meters) from the ground **99**.

[0045] As shown in **FIG. 11**, the present invention's seven individual material systems **200** -- namely, three-layer wheel well system **200W**$_{FL}$, three-layer wheel well system **200W**$_{FR}$, three-layer wheel well system **200W**$_{RL}$, three-layer wheel well system **200W**$_{RR}$, three-layer floorboard system **200FL**, three-layer floorboard system **200FR**, and two-layer central underside system **200C** -- collectively describe a kind of protective enclosure for cabin **14** that shields the cabin occupants from serious harm. Otherwise expressed, the present invention's cumulative protective "system" is shown to include seven "sub-systems" **200**. According to generally preferred inventive practice, the overall protective arrangement includes seven systems **200** similarly as shown in **FIG. 11**. The seven systems (or sub-systems) **200** collectively form, for cabin **14**, a buffer unit or shield

unit generally describing a shape that can variously but equivalently described as that of a "half-shell," "dish" or "boat hull."

[0046] Three-layer floorboard system **200FL**, three-layer floorboard system **200FR**, and two-layer central underside system **200C** are next to each other, the combination thereof approximately defining a horizontal geometric plane **h**. Each three-layer wheel well system **200W** is contiguous to its corresponding three-layer floorboard system **200F**. According to typical inventive practice, each wheel well system **200W** is disposed at an angle θ (shown in **FIG. 5**) that is in the range between forty-five degrees and ninety degrees (i.e., verticality of wheel well system **200W**) with respect to the horizontal geometric plane **h** defined by underside systems $\mathbf{200F_{FL}}$, $\mathbf{200F_{FR}}$ and **200C**. That is, each wheel well system **200W** is disposed at an angle (90-θ)° that is in the range between 45° and 0° (i.e., verticality of wheel well system **200W**) with respect to a vertical geometric plane that passes through the junction between wheel well system **200W** and its corresponding floorboard system **200F**.

[0047] According to typical inventive practice, the width of each material system **200** is commensurate (or approximately so) with the width of the vehicle component or region covered by such material system. As illustrated in **FIG. 8** through **FIG. 11**, wheel wells **18** and their adjoining floorboards **28** are approximately equal in width (width being a dimension directed laterally across vehicle **10**, between the vehicle's left and right sides). This widthwise equivalence is a design feature of a typical HMMWV. Thus, as shown in **FIG. 11**, wheel well systems $\mathbf{200W_{FL}}$ and $\mathbf{200W_{RL}}$ are each approximately coextensive with floorboard system **200FL**, and wheel well systems $\mathbf{200W_{FR}}$ and $\mathbf{200W_{RR}}$ are each

approximately coextensive with floorboard system **200FR**. Many vehicular makes and models are characterized by narrower wheel well widths than floorboard widths. Inventive practice is effectual regardless of the relative widths of the wheel wells and floorboards.

[0048] Some inventive embodiments represent variations on the inventive theme depicted in **FIG. 11**. If the applicative context permits, significant protection to the vehicle occupants, albeit usually at a reduced level, can be inventively afforded when one or more of the seven regions of interest (front left wheel well **18FL**; front right wheel well **18FR**; rear left wheel well **18RL**; rear right wheel well **18RR**; left floorboard region **28L** of cabin underside **26**; right floorboard region **28R** of cabin underside **26**; central region **30** of cabin underside **26**) has associated therewith either no system **200** or a modified version thereof. In this regard, for instance, a diminished but perhaps still worthwhile degree of protection can be obtained when ERC material **210** alone is applied, in the absence of non-elastomeric (rigid) material **200**, to one or more wheel wells **18** or to either or both floorboard regions **28**.

[0049] Moreover, ERC **210** can be applied to either or both sides of a vehicular wall so that a material system **200** is established at either or both sides of the vehicular wall. For instance, in the front left wheel well **18FL** or front right wheel well **18FR** region, a material system **200W** can be provided wherein ERC layer **210** is applied to the back side (rather than or in addition to the front side) of wheel well **18FL** or **18FR** so that the rigid material layer **220** is facing toward the rear (rather than or in addition to the front) of vehicle **10**. Similarly, a material system **200W** can be provided wherein ERC layer **210** is applied to the frontward side (rather than or in addition to the rearward side) of wheel

well **18RL** or **18RR** so that the rigid material layer **220** is facing toward the front (rather than or in addition to the rear) of vehicle **10**. Further, a material system **200F** can be provided wherein ERC layer **210** is applied to the upper side (rather than the lower side) of floorboard **28L** or **28R** so that the rigid material layer **220** is facing upward (rather than downward).

[0050] Generally speaking, inventive practice admits of wide variations in terms of materials, configurations, and installation techniques. ERC material **210** can be any elastomer, natural or polymeric, such as polyurea, polyurethane, or rubber. ERC material **210** can be applied by casting it in place, or by spraying it, or by bonding it as a whole, individual piece. Rigid material **220** can be any non-elastomeric material having the requisite stiffness, such as a metal or composite. Rigid material **220** can be characterized by any thickness. ERC material **210** can be characterized by any thickness.

[0051] The example described herein with reference to the figures illustrates inventive practice for purposes of HMMWV protection; nevertheless, the present invention admits of practice in association with wheeled vehicles of diverse designs, including automobiles, buses, trucks, sports utility vehicles, limousines, etc. For instance, inventive principles are applicable not only to four-wheeled passenger vehicles but also passenger vehicles having more than four wheels (e.g., six-wheeled or eight-wheeled passenger vehicles). Generally, regardless of the number of pairs of axial wheels, the two longitudinally extreme (i.e., front-most and rear-most) pairs of wheel wells are treated as inventive practice will typically dictate for a four-wheeled passenger vehicle, and the intermediate pair or pairs of wheel are treated similarly.

[0052] For instance, a vehicle may have an even number greater than two (e.g., four, six, etc.) of longitudinally uniformly spaced pairs of axial wheels; according to some such inventive embodiments, the wheel wells in the longitudinal front half of the vehicle are treated as if they are the front wheel wells of a four-wheeled vehicle, while the wheel wells in the longitudinal rear half of the vehicle are treated as if they are the rear wheel wells of a four-wheeled vehicle. As another example, a vehicle may have an odd number greater than one (e.g., three, five, etc.) of longitudinally uniformly spaced pairs of axial wheels; according to some such inventive embodiments, each of the longitudinally intermediate (neither front nor rear) pair of wheel wells is covered in two areas that face each other, as if they are at once both front wheel wells and rear wheel wells.

[0053] The present invention is not to be limited by the embodiments described or illustrated herein, which are given by way of example and not of limitation. Other embodiments of the present invention will be apparent to those skilled in the art from a consideration of this disclosure or from practice of the present invention disclosed herein. Various omissions, modifications and changes to the principles disclosed herein may be made by one skilled in the art without departing from the true scope and spirit of the present invention, which is indicated by the following claims.